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Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington DC 20554

**Re: ET Docket No. 18-295, *Unlicensed Use of the 6 GHz Band***
**GN Docket No. 17-183, *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz***
***Ex Parte* Communication**

Dear Ms. Dortch:

The Fixed Wireless Communications Coalition (FWCC) responds to an *ex parte* filing from RLAN proponents dated July 31, 2019 (July 31 filing).[1]

## A. INTRODUCTION

Fixed Service (FS) systems in the 6 GHz bands carry safety-critical services at very high levels of reliability. Because unlicensed RLANs pose a severe interference threat to these services, we initially opposed their authorization. When RLAN proponents suggested using Automatic Frequency Control to coordinate their devices around FS receivers, we withdrew our objection, subject to the AFC system being properly designed and implemented.

In what feels like a bait-and-switch, the RLAN interests now argueð contrary to sound engineering analysisð that outdoor RLAN devices at 14 dBm, and indoor devices at 30 dBm, can operate free of AFC control without causing interference to FS receivers. Their July 31 filing is one of a series of

1 Letter from Paul Margie, Counsel to Apple Inc. *et al.*, to Marlene H. Dortch, Secretary, FCC (July 31, 2019), and attachment.

unsuccessful attempts to make this case. We have shown in prior docket submissions, and reiterate here, that uncontrolled RLANs at any useful power will cause harmful interference to the FS.

The RLAN proponentsô present filing includes many of the same factual errors and contrary-to-fact assumptions as its predecessors, and adds a few more. We show below that the RLAN filing, after its errors and assumptions are corrected, makes a strong case ***against*** uncontrolled RLANs.

To lawfully authorize unlicensed 6 GHz RLANs, the Commission must find they present no significant potential for harmful interference to FS receivers.[2] The Commission cannot rationally make that finding as to RLANs that lack AFC control. The proponents have admitted that their interest in non-AFC RLANs is in part to promote favorable ñdevice price pointsò[3]ð a consideration subordinate to the Commissionôs obligation to prevent unlicensed devices from causing harmful interference to licensed, safety-critical services.

### B. RLAN PROPONENTS' FUNDAMENTAL ERROR

The July 31 filing repeats a fallacy that recurs throughout the docket. Even if we take all of the proponentsô overly optimistic assumptions about RLAN location and signal attenuation as being correct in every case, at best their analysis shows a low probability of interference ***from a single RLAN at a typical location***. But the proponents seek to deploy 958,062,017 RLANs.[4] Large numbers drastically alter the probabilities. If a single RLAN presented an interference risk of only one in a trillion, then to deploy 958,062,017 such RLANs raises the overall interference risk to 0.1% ð a number that predicts interference into over 90 FS receivers.[5] The claim of an ñextremely lowò interference risk[6] is not credible.

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2 *American Radio Relay League, Inc. v. FCC*, 524 F.3d 227, 234-35 (D.C. Cir. 2008). For a discussion of the legal issues, *see* Reply Comments if the Fixed Wireless Communications Coalition at 7-8 (filed March 18, 2019).

3 Letter from Paul Margie, Counsel to Apple Inc., *et al*., to Marlene Dortch, Secretary, FCC at 1 (filed July 19, 2019).

4 *Frequency Sharing for Radio Local Area Networks in the 6 GHz Band January 2018*, *attached to* Letter from Paul Margie, Counsel to Apple Inc., *et al*., to Marlene Dortch, Secretary, FCC, in GN Docket No. 17-183 at 12, Table 3-1 (filed Jan. 26, 2018) (RKF Study).

5 If the probability of one RLAN causing harmful interference is 1 in a trillion ($10^{-12}$), the probability of one or more of 958,062,017 deployed RLANs causing harmful interference is

$[1-(1-10^{-12})^{958,062,017}] = 0.00096$ å 0.1%.

Multiplying this probability by the 97,000 FS links in the 6 GHz band predicts about 93 interfered-with FS links.

6 July 31 filing at slide 2.

Broadcom cites with approval a U.K. study showing ñonly a one in 100 million probabilityò that an uncontrolled RLAN would meet or exceed the studyôs interference criterion 2 percent of the time.[7] Broadcomôs 1 in 100 million probability is fully four orders of magnitude worse than the one-in-a-trillion calculation above, and would cause vastly more FS interference.[8] Moreover, to exceed the criterion two percent of the time is wholly unacceptable for a legally protected FS service that routinely operates at 99.999% or 99.9999% reliability. Broadcomôs citation supports our argument that uncontrolled RLANs are virtually certain to cause FS interference.

As before, we emphasize that the enormously increased risk from very large numbers of RLANs is ***not*** due to signal aggregation from multiple devices. (None of our analyses considers aggregate interference.) Rather, the greatest risk of FS interference comes from a single RLAN in or near the main beam of an FS receiver, with little or no intervening clutter. The mathematics shows that large numbers of projected RLANs ensure this kind of configuration will occur far too often. That is why all RLANs must be under AFC control.

### C. Misuse of Average Values

The RLAN proponentsô analyses rely on taking averages over multiple interference situations. For example, all of the link budgets in the July 31 filing use the identical numbers for building entry loss (30 dB) and RLAN pattern mismatch (5 dB).[9] These are not actual data, but only estimated averages. Similarly, the proponents cite a ñmedian C/Nò as showing lack of interference.[10] Elsewhere in the docket, RLAN proponentsô analyses use averages for FS receiver height,[11] FS off-axis gain,[12][13] and clutter attenuation (through propagation models developed for other purposes).[14]

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7 Comments of Broadcom at 21 (filed Feb. 15, 2019), *citing Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz*, ECC Report 302 at 72 (approved 29 May 2019), available at (may have to copy link into browser address field):
https://www.ecodocdb.dk/download/cc03c766-35f8/ECC%20Report%20302.pdf
(Broadcom cited a draft version of the report that included the same statement; the citation here is to the final version.)

8 Repeating the calculation in note 5 for an interference probability of 1 in 100 million ($10^{-8}$) per RLAN, for 958,062,017 RLANs, yields an overall probability estimate in excess of 99.99%.

9 July 31 filing at slides 12, 14, 16, *et al*.

10 July 31 filing at slide 2.

11 Comments of Apple, Inc., *et al,* at 20 (filed Feb. 15, 2019).

12 *Id*.

13 Letter from Apple Inc., *et al*., to Marlene H. Dortch, Secretary, FCC in GN Docket No. 17-183 at 18 (filed May 14, 2018).

14 RKF Study at 33.

This use of averages smooths out the peaks and valleys that characterize real-world interference. The result is an artificially flat terrain that looks harmlessð but only because the averaging process misleadingly removes the cases that cause actual interference: the atypical RLAN in an FS main beam with little or no clutter.

The study cites median distances.[15] These are irrelevant. The use of median values masks the atypical cases, which comprise the real interference threats.

The RLAN proponents accuse the FWCC of focusing on ñisolated and hypothetical scenarios,ò while ignoring the real-world relationships that make interference (in their words) extremely unlikely.[16] We do this because the isolated scenarios are what cause real-world FS interference. Even if some given scenario were unlikely for one RLAN, it would become extremely likely, many times over, with almost a billion RLANs in the field.

## D. ERRORS IN STUDY ASSUMPTIONS

### *1. Building entry loss*

Every case in the RLAN study assumes a building entry loss (BEL) of 30 dB,[17] relying on the statement that ñ[n]umerous filings in the record document that virtually all high-rise buildings are thermally efficient (30 dB BEL) for structural reasons.ò[18]

Applying this assumption would make sense only if all of the buildings in an FS receiver main beam in fact were high-rises. Figure 1 shows that even small buildings of conventional construction can come within the main beam of a Category A or B1 antenna just a few kilometers away, at distances close enough for RLANs to cause severe interference.[19]

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15 *E.g.*, July 31 filing at slides 2, 10.

16 Reply Comments of Apple, *et al*., at 19 (filed March 18, 2019).

17 July 31 filing at slides 12 14, 16 *et al*. Also called ñbuilding attenuationò or ñwall attenuation,ò BEL is the amount by which the building structure diminishes the signal escaping from an indoor RLAN into the outdoors.

18 July 31 filing at slide 7.

19 In Figure 1, the Category A or B1 antenna corresponds to an antenna gain of 38 dBi. 47 C.F.R. § 101.115(b)(2). This is middle-of-the-road for the July 31 study, whose median gain among the eight antennas cited is 38.9 dBi. The 43 meter FS antenna height in Figure 1 is a value that proponents have used in several calculations. *E.g.*, Comments of Apple, Inc., *et al*., at 9 & n.22 (filed Feb. 15, 2019); Comments of Broadcom at 7-8 (filed Feb. 15, 2019).

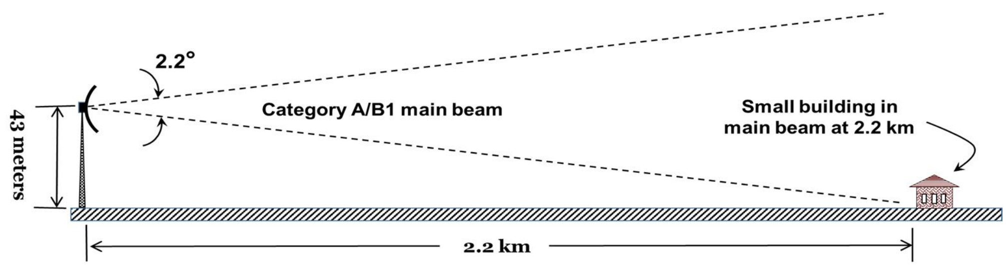


**Figure 1**: Category A/B1 Main beam

Table 1 summarizes BEL studies put forward in the proceeding by RLAN interests. (The table omits unsupported assertions, and also omits studies cited only by RLAN opponents.) These numbers support the proponentsô 30 dB BEL value for modern, thermally efficient construction. But they show much lower BEL values (in boldface, 16-18 dB maximum) for traditionally constructed buildings, which can easily fall in the FS receiver main beam.[20]

It is entirely possible for a New York City indoor RLAN to be in an FS main beam behind a wall that attenuates by only 16-18 dBð or by zero dB, if behind a window in a traditional older building. Under line-of-sight conditions, this last case will cause interference from a distance limited only by the curvature of the Earth.[21] As we showed in Part B above, deploying almost a billion RLANs makes even highly unlikely combinations virtually certain, many times over.

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[20] Urban FS interference most often occurs when the interfering source has line-of-sight to an FS receiver along a street with no intervening clutter.

[21] See Part D.5, table 3, below.

| Party | Date filed | Trad. Constr. (dB) | Therm. Effic.* (dB) | Notes |
|---|---|---|---|---|
| RLAN Group | 2019-03-08 | | 25-70 | at A-1 |
| Leading Builders Of America | 2019-02-15 | **18** | 30 | at 6, citing to ITU P.2109 |
| | | 18-29 | | at nn. 7 ***et seq***. citing to ITU-R P. 2346-2 at 26 |
| Wi-Fi Alliance | 2019-02-15 | | > 30 | at 12-13 & n.39, ***misrepresents*** cited graphic, Ofcom 2604/BMEM/R/3/2.0 at Fig.4.4 |
| | | **< 3.5** | | ***non-cited*** graphic, Ofcom 2604/BMEM/R/3/2.0 at Fig. 4.5 |
| RLAN Group | 2019-02-15 | **18** | 30 | at E-2, citing to ITU P.2109 |
| | | | 40 | citing 5G White Paper at 12-13 & fig. 6 |
| | | 5-25 | | ***non-cited*** from 5G White Paper at 13 fig. 7 |
| Wi-Fi Alliance | 2018-08-08 | 20 | | at Appendix (assumed without support) |
| IEEE | 2017-10-02 | **16** | 31 | at § IV, citing to ITU P.2109 (at Fig. 1) |
| ñIncludes thermally efficient windows | | | | |

**Table 1**: BEL studies provided or cited by RLAN proponents

The proponentsô study results are sensitive to the assumed BEL. Figure 2 is a modified reproduction of the RLAN proponentsô July 31 filing, slide 10. The study asserts that only a few of the studied cases cause interference above the I/N = -6 dB criterion, as marked by the upper dotted line.[22] Reducing the assumed BEL from thermally efficient to traditional constructionð from 30 to 17 dBð is equivalent to moving the dotted line down by 13 dB, after which nearly all of the same cases fall above the line, meaning they would cause interference ***in excess*** of the same criterion.

[22] July 31 filing at slide 2.

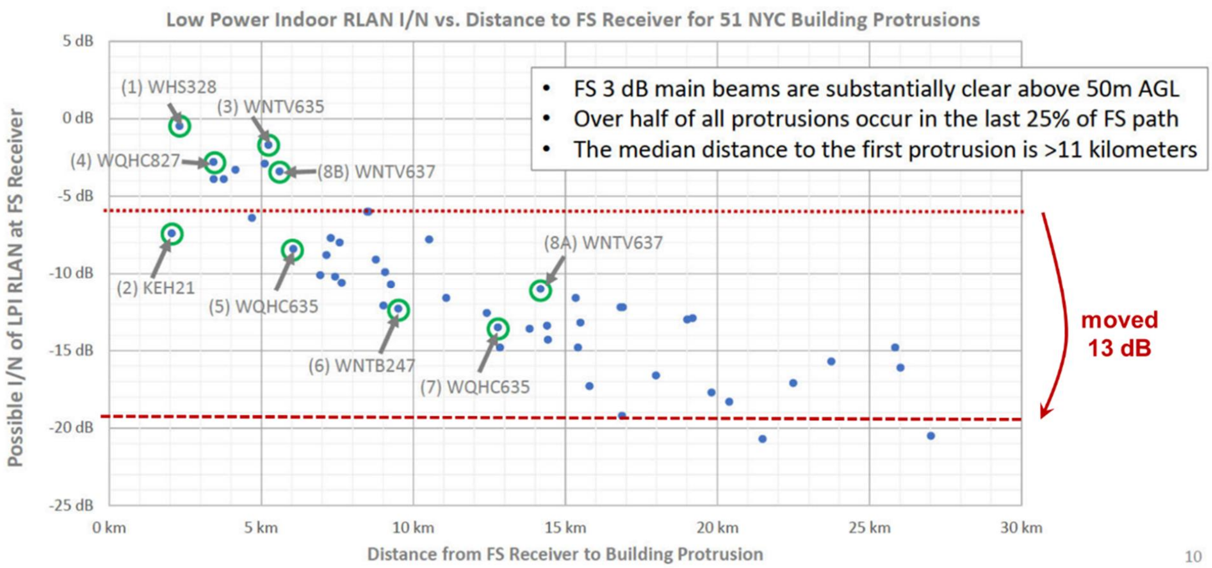


**Figure 2**: RLAN proponentsôfigure modified to show BEL reduced by 13 dB
(modified from July 31 filing at slide 10)

The foregoing does not make any claim about the actual BEL of the cases studied. We seek only to show that proponentsôresults require the assumption that all buildings in the main beam are of thermally efficient construction. If that assumption is wrongð and we explain above why it almost certainly isð then proponentsôdata confirm our view that uncontrolled RLANs, even indoors, will cause interference to the FS.

### 2. *Misuse of fade margin*

The proponents try to explain away their cases that predict RLAN interference above the criterion by relying on incursions into the FS receiver fade margin, adding the claim that adequate ñresidual marginò will remain.[23]

As we explained in a recent filing, fade margin is expensive.[24] FS designers evaluate the climate, path length, and other specifics for each individual link, so as to provide the minimum fade margin needed to maintain the rated reliability for that link. Design margin is not ñexcessò margin. ***There is no excess fade margin.***

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23 *E.g.*, July 31 filing at slides 12, 14, 16, *et al*.

24 Letter from Donald J. Evans and Mitchell Lazarus, Counsel, FWCC, to Marlene H. Dortch, Secretary, FCC (filed July 25, 2019).

Any RLAN interference that encroaches on fade margin will reduce FS reliability by raising the likelihood of outages during fades. Every 10 dB of fade margin taken up by an RLAN increases FS outage times by a factor of 10, and takes one ñ9ò off the reliability.

### 3. *Incorrect signal-to-noise ratio*

The RLAN proponents make serious errors in estimating the FS required signal-to-noise (SNR) ratio. The errors contribute to proponentsô finding nonexistent ñexcessò fade margin.

Table 2 shows the incorrect SNR numbers the proponents used in their calculations, and the correct values.

| RLAN Link Example # | RLAN July 31 slide number | July 31 Incorrect SNR (dB) | Correct SNR (dB) | Overstated Fade Margin (dB) |
|---|---|---|---|---|
| 1 | 12 | *analog link*[a] | | |
| 2 | 14 | *analog link*[a] | | |
| 3 | 16 | 15.3 | 26.2[b] | **10.9** |
| 4 | 18 | 17.2 | 25.2 or 26.2[c] | **8.0 or 9.0** |
| 5 | 20 | 17.2 | 25.2 or 26.2[c] | **8.0 or 9.0** |
| 6 | 22 | 17.2 | 25.2 or 26.2[c] | **8.0 or 9.0** |
| 7 | 24 | 17.2 | 25.2 or 26.2[c] | **8.0 or 9.0** |
| 8 | 27 | 15.3 | 26.2[b] | **10.9** |

[a] Fewer than 3 percent of 6 GHz links are analog.
[b] George Kizer, *Digital Microwave Communication* at 64, table 3.4 ( 2013)
[c] *Id.* at 73, table 3.5, or 64, table 3.4, according to whether the TCM is 2D or 4D

**Table 2**: RLAN Proponents' values and correct values for required FS SNR

By understating the required SNR, the RLAN proponents create an illusory 8-10.9 dB of fade margin (shown in the right-hand column), which they claim will cushion interference into FS systems. Because that extra fade margin is fictitious, the proponentsô plans would cut into the actual fade margin by the same 8-10.9 dB, which in turn would cause outage times to increase by a factor of 6.3 to 12.3.[25]

### 4. *Misuse of "pattern mismatch"*

Each of the eight link budgets in the July 31 filing subtracts 5 dB from the RLAN interference power for ñpattern mismatch.ò[26] The subtraction is intended to account for the possibility that the main lobe of an

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25 This assumes links without space diversity. Links with space diversity would suffer greater increases in outage.

26 July 31 filing at slides 12, 14, 16, *et al.*

RLAN antenna pattern may not always aim directly at the FS receiver, and in that event, will transmit less power toward the FS receiver.[27]

As we explained in Part C above, applying the same average value indiscriminately to every case masks out the individual cases most likely to cause actual interference.

Moreover, the assumed (and unexplained) 5 dB average is unrealistically high. RLAN proponents expect 50-70% of devices to be access points, as opposed to client devices.[28] Most access points are hung from ceilings or placed on tabletops,[29] and radiate primarily in the horizontal plane. As shown in Figure 3, the path from the RLAN transmit antenna to the FS receive antenna will be within a few degrees of the horizontal. But the RLAN antenna pattern (for a ceiling or tabletop device) shows negligible attenuation within about 20 degrees of horizontal.[30] For an angle steep enough to provide even minimal pattern attenuation toward an FS antenna 43 meters above ground,[31] a worst-case ground-level RLAN would have to be within 118 meters of the tower base. At all greater RLAN distances or elevations, the attenuation due to ñpattern mismatchò from an access point is essentially zero. As a result, the average pattern mismatch for all RLANs cannot reach the assumed 5 dB unless ***every*** non-access-point RLAN (client device) device always points at least 75 degrees away from the FS tower. We find that improbable.

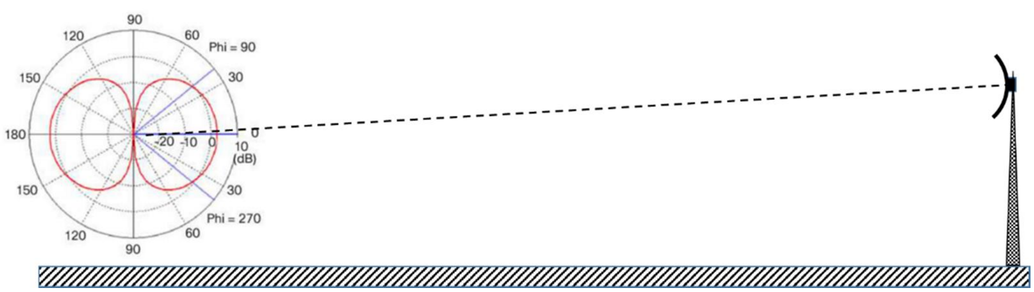


**Figure 3**: Interference path from ceiling-mounted or tabletop RLAN to FS receiver

In any event, the average pattern attenuation is irrelevant. (See Part C, above.) The fact that most RLAN access points will have near-zero antenna attenuation in the direction of the FS antenna is reason enough to eliminate that 5 dB from the interference link budget.

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27 *See*, *e.g.*, Comments of Broadcom, Inc. at 12-13 (filed Feb. 15, 2019); Comments of Apple, Inc., *et al*., at Exhibit D ¶¶ 11-17 (filed Feb. 15, 2019); Letter from Paul Margie, Counsel to Apple, Inc., *et al*., to Marlene H. Dortch, Secretary, FCC, attachment at slides 13-14 (filed June 24, 2019).

28 RKF Study at 22, tables 3-5, 3-5 (busy hour distribution).

29 Reply Comments of Apple, *et al*., at 22 (filed March 18, 2019).

30 The RLAN antenna pattern in Figure 3 comes from Comments of Broadcom, Inc. at 13, figure 4(d) (filed Feb. 15, 2019).

31 See note 19.

### *5. Miscalculation of bandwidth mismatch*

Each of the eight link budgets in the July 31 filing subtracts a value for ñbandwidth mismatch.ò[32] This entry reflects the expectation that an RLAN channel bandwidth will generally be greater than an FS channel bandwidth, so that some RLAN power will fall outside the FS receiver bandwidth and not affect the link.

We agree with the principle, but not with the calculation.

Each of the eight link budgets specifies an RLAN bandwidth, always 80 MHz, and an FS bandwidth that varies from 5 to 30 MHz.[33] The numerical results show the RLAN proponents calculated the mismatch as follows:

$$\text{Bandwidth mismatch (in dB)} = 10 \times \log_{10} \left( \frac{\text{RLAN channel bandwidth}}{\text{FS channel bandwidth}} \right)$$

The error in the calculation is a failure to account for RLAN interference into frequencies outside but adjacent to the FS receive channel.

Some RLAN proponents have argued that RLAN out-of-band emissions limits make adjacent channel protection unnecessary,[34] but that misunderstands the physics. Every radio receiver is sensitive to frequencies outside but close to the channel it is tuned to.[35] This is not a matter of poor design, but reflects fundamental properties of electronic circuitry. It is the reason why the Commission must require geographical separation between broadcast stations on adjacent and second-adjacent channels.[36] It is why FS frequency coordinators must routinely address adjacent channel interference with complex, case-by-case calculations.[37]

To correctly predict RLAN interference, the denominator in the above equation must increase to include the frequencies on either side of the FS channel bandwidth that are susceptible to RLAN interference. These typically amount to about half the channel bandwidth, on either side.[38] In the link budgets, this

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[32] July 31 filing at slides 12, 14, 16, *et al.*

[33] The selection of atypically narrow 5 and 10 MHz FS channels artificially increases the subtraction for bandwidth mismatch.

[34] Comments of the Wireless Internet Service Providers Assôn at 21 (filed Feb. 15, 2019).

[35] Comments of the Fixed Wireless Communications Coalition Comments at 25 (filed Feb. 15, 2019).

[36] 47 C.F.R. §§ 73.37, 73.207, 73.623.

[37] Comments of the Fixed Wireless Communications Coalition Comments at 27 (filed Feb. 15, 2019).

[38] Reply Comments of the Fixed Wireless Communications Coalition at 32-33 (filed March 18,

reduces the subtraction for bandwidth mismatch by about 3 dB, and increases the potential for RLAN interference into the FS by a like amount.

### *6. Underestimates of interference distances*

In cases where the actual (not average) building attenuation is low, distance alone offers little protection. For a typical FS receiver configuration, Table 3 shows the interference distances for the case of an RLAN in the FS receiver main beam, for several values of BEL:[39]

| BEL (dB) | Interference distance (km) |
|---|---|
| 30 | 10.5 |
| 20 | 33.0 |
| 10 | 105 |
| 0 | 330* |
| * limited by curvature of the Earth | |

**Table 3**: Interference distance *vs.* BEL

As noted above, interference properties are sensitive to the BEL value. A drop in BEL just from the proponentsô assumed 30 dB to 20 dBð still high for traditional constructionð more than triples the interference distance, and multiplies almost tenfold the area within which FS receivers are exposed to interference.

## E. STUDY RESULTS

Despite the unduly favorable assumptions and other errors noted above, the proponentsô July 31 study still predicts alarming levels of interference. A few examples:

- ***High fraction of cases causing interference***. The study asserts that under stated conditions the RLAN signal would exceed the interference criterion in 2.7% of cases[40]ð as though that were a small number. Unlicensed systems must protect all existing licensed users, not just 97.3% of them. Extrapolating to 97,000 FS links nationwide, a 2.7% interference rate predicts interference into more than 2,600 links. Any case that violates the interference criterion is unacceptable.

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2019).

[39] Assumptions and methodology are detailed in Attachment A. In accordance with Part D.4 above, the calculations do not include attenuation due to the RLAN antenna pattern. They do include 4.3 dB of bandwidth mismatch.

[40] July 31 filing at slide 9.

- ***Implicit reliance on fade margin***. While conceding that a percentage of FS links will receive over-threshold RLAN signals, the study asserts that ñsmall exceedancesò will not cause harmful interference.[41] In the absence of explanation, we must assume proponents are counting on excess FS fade margin to soak up the interfering RLAN signal. As explained in Part D.2 above, there is no excess fade margin. Any RLAN signal over the interference threshold increases the likelihood and duration of outages, and thereby reduces reliability.

- ***Distances to protrusions***. The study asserts that the median distance to the first ñprotrusionò of a building into an FS main beam exceeds 11 km.[42] The median distance is irrelevant; all buildings in the main beam, within the distances shown in Table 3, are potential sources of interference. Moreover, because the top line in Table 3 shows the threshold interference distance to be 10.5 km, even under proponentsô assumption of 30 dB BEL for all buildings, RLANs in almost half of the buildings in the main beam will exceed the interference threshold.

## CONCLUSION

The deployment of uncontrolled RLANs in large numbers at any useful power will cause harmful interference to the FS. The only way the Commission can meet its legal obligation to protect FS receivers from harmful interference is to place all RLANs under AFC control, regardless of their power or location.

Respectfully submitted,

Donald J. Evans
Mitchell Lazarus
Seth L. Williams
Counsel for the Fixed Wireless
Communications Coalition

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41 July 31 filing at slide 9.

42 July 31 filing at slide 10.

# ATTACHMENT A

## RLAN INTERFERENCE ESTIMATION

George Kizer

### Victim Receiver Interference I

To determine the threshold impact of interference, we must first estimate the interference power I at the receiver. The interference received at the victim receiver may be diagramed below:

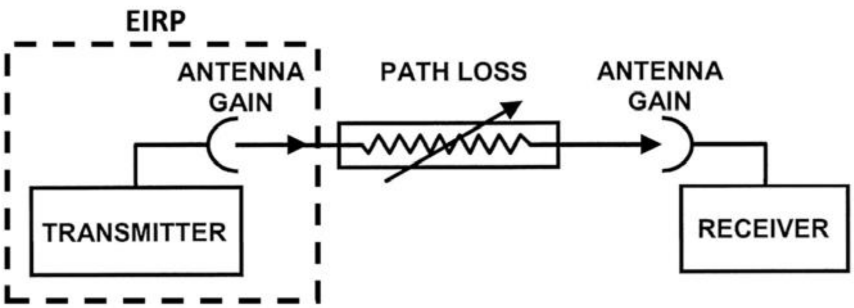



**Figure 1 – Typical Radio Transmission Path**

If we assume the transmitter and victim receiver are tuned to the same center frequency (co-channel interference), victim receiver interference may be estimated using the following formula:

Victim Receiver Interference (dBm) = RLAN EIRP - Path Loss - Environmental Loss
+ Receiver Antenna Gain - Side Lobe Rejection - Near Field Loss
- Bandwidth Mismatch Loss - Polarization Decoupling Loss
- Pattern Mismatch - FS RX Feeder Loss (1)

**RLAN EIRP (dBm)** is the combined RLAN transmitter power (dBm) plus antenna gain (dBi).

**Path Loss (dB)** is the propagation loss between the RLAN transmitter and victim receiver antennas. For this calculation (see text) we assume Path Loss is free space loss[1]:

Free Space Path Loss (dB) = 92.5 + 20 Log [Frequency (GHz)]
+ 20 Log [Path Distance (kilometers)] (2)

**Environmental Loss (dB)** is the additional loss that the transmitted signal encounters. Typically this is only significant for indoor transmitters where it is called Building Entry Loss. This value will vary with location.

**Receiver Antenna Gain (dBi)** is the antenna boresight gain. This varies with operating frequency and antenna size and design.

**Side Lobe Rejection (dB)** is the loss of antenna gain when the interfering path is off azimuth from the bore sight path. For bore sight interference, this value is zero.

[1] G. Kizer, *Digital Microwave Communication*. Hoboken: Wiley and Sons, 2013, page 669, formula A.28.

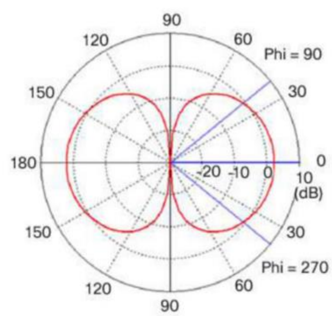
**Near Field Loss (dB)** is the loss of antenna gain when the transmitter is in the near field of the receiver antenna. For this calculation its value is zero.

**Bandwidth Mismatch Loss (dB)** is the loss of interference power if the interfering signal bandwidth is not completely within the victim receiver bandwidth.

Bandwidth Mismatch Loss (dB) = 10 Log$_{10}$ [ Expected RLAN transmitter bandwidth / victim receiver bandwidth (MHz) ]
if expected RLAN transmitter bandwidth Óvictim receiver bandwidth (3)
Bandwidth Mismatch Loss (dB) = 0 dB
if expected RLAN transmitter bandwidth Òvictim receiver bandwidth (4)

**Polarization Mismatch Loss (dB)** is the loss introduced when the transmitter antenna polarization is not aligned with the receiver antenna polarization. We will assume the RLAN transmit antenna can assume any polarization[2]. Since the receiver antenna will be either vertical or horizontal polarization, on average we would expect a 3 dB antenna to antenna polarization mismatch loss. This value will vary and is an estimate.

**RLAN Pattern Mismatch (dB)** accounts for reduction of the RLAN antenna gain when the interference path is above or below the horizontal (azimuth) plane directly in front of the RLAN antenna. The expected antenna pattern[3] in the elevation plane is shown below:




If the interference path is much above or below 0˚ or 180° degrees in n vertical (elevation) plane, the RLAN antenna gain is reduced. For this calculation the reduction in gain is zero. See text Part D.4.

**FS RX Feeder Loss (dB)** is the loss between the FS receive antenna and the input to the FS receiver. This information is not in the ULS database and is therefore an estimate.

**Threshold Degradation and Receiver Front End Noise N**

Receiver path performance is a direct function of path fade margin. Fade margin is limited by the combined power level of receiver front end noise and external interference, given by the following formula:

(5)

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[2] Paul Margie, *Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz*, GN Docket No. 17-183, Harris, Wiltshire & Grannis, filed January 26, 2018, Paragraph 3.2.1, page 17, ñIn each installation, the orientation of the RLAN antenna is in general not fixed. Therefore, in the analysis we assumed an equal weight assigned to all values in the E-plane pattern.ò

[3] Comments of Broadcom Inc., February 15, 2019, page 13, Figure 4

RFM = Reduction in Fade Margin (dB) = Threshold Degradation
RFM = $\{10 \log10 [\ 10^{N/10} + 10^{I/10}\ ] \}$ ï N
N = Receiver Front End Noise (dBm)
I = External Interference (dBm)

Most authorities suggest limiting interference to I/N = -6 dB. For purposes of illustration, set N to 0 dB and I to -6 dB (I/N = -6 dB). The result is a reduction in fade margin of 1 dB.

Receiver front end noise N is given by the following:[4]

N(dBm) = ï 114 + NF + 10 Log(B) (6)
NF = receiver noise figure (dB)
B = receiver bandwidth (MHz)

RLAN Group suggests the typical receiver noise figure in this band is about 5 dB,[5] so

N(dBm) = ï 109 + 10 Log(B) (7)

**Table A-1**: Interference distance as a function of building loss

| | | | | |
|---|---|---|---|---|
| FS Rx Center Freq (GHz) | 6.034 | 6.034 | 6.034 | 6.034 |
| FS Rx Bandwidth (MHz) | 30 | 30 | 30 | 30 |
| FS Rx Antenna Gain (dBi) | 38.9 | 38.9 | 38.9 | 38.9 |
| FS Rx Antenna Off-Axis Rejection (dB) | 1.4 | 1.4 | 1.4 | 1.4 |
| FS Rx Antenna Near Field Loss (dB) | 0 | 0 | 0 | 0 |
| FS Rx Feeder Loss (dB) | 2 | 2 | 2 | 2 |
| FS Rx Noise Floor (dBm) (per docket) | -94.2 | -94.2 | -94.2 | -94.2 |
| FS Rx Noise Floor (dBm) (calculated) | -94.2 | -94.2 | -94.2 | -94.2 |
| **Interference Path Distance (km)** | **330** | **105** | **33** | **10.5** |
| Interference Path Free Space Loss (dB) | 158.4 | 148.5 | 138.4 | 128.5 |
| RLAN Tx Center Freq (GHz) | 6.034 | 6.034 | 6.034 | 6.034 |
| RLAN Tx Output Power (dBm) | 24 | 24 | 24 | 24 |
| RLAN Tx Antenna Gain (dBi) | 6 | 6 | 6 | 6 |
| RLAN Tx EIRP (dBm) | 30 | 30 | 30 | 30 |
| RLAN Tx Channel Bandwidth (MHz) | 80 | 80 | 80 | 80 |
| **Building loss (dB)** | **0** | **10** | **20** | **30** |
| Polarization Loss (dB) | 3 | 3 | 3 | 3 |
| Pattern Mismatch (dB) | 0 | 0 | 0 | 0 |
| Bandwidth Mismatch (dB) | 4.3 | 4.3 | 4.3 | 4.3 |
| I @ FS RX (dB) | -100.2 | -100.2 | -100.2 | -100.2 |
| I/N @ FS RX (dB) | -6 | -6 | -6 | -6 |
| FS Rx Threshold Degradation (dB) | 1 | 1 | 1 | 1 |

[4] Kizer, G., *Digital Microwave Communication*, page 674, formula (A.54), Hoboken: Wiley and Sons, 2013.
[5] RKF Study at 29.